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(54) PROCESS FOR POLYMERIZING OLEFIN.

(57) A process for polymerizing olefin which comprises using a catalyst comprising a transition metal catalyst component, an aluminoxane component, and an organo-aluminum component. In this process, a catalyst containing a reduced amount of the above-described aluminoxane is used to attain an excellent polymerization activity. This process affords a polymer with a narrow molecular weight distribution, while it affords an olefin copolymer having a narrow molecular weight distribution and a narrow composition distribution in a copolymerization of two or more olefins.

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SPECIFICATION

PROCESS FOR POLYMERIZING OLEFINS

TECHNOLOGICAL FIELD

This invention relates to a process for polymerizing olefins. More specifically, it relates to a process for producing an olefin polymer of a narrow molecular weight distribution by polymerizing an olefin with a catalyst showing excellent polymerization activity using a small amount of an aluminoxane, which when applied to the copolymerization of at least two olefins, can give a copolymer having a narrow molecular weight distribution and a narrow composition distribution.

BACKGROUND TECHNOLOGY

[Prior Art]

For the production of an alpha-olefin polymer, particularly an ethylene polymer or an ethylene/alpha-olefin copolymer, methods have previously been known in which ethylene is polymerized, or ethylene and an alpha-olefin are copolymerized, in the presence of a titanium-containing catalyst comprising a titanium compound and an organoaluminum compound or a vanadium-containing catalyst comprising a vanadium compound and an organoaluminum compound. Generally, ethylene/alpha-olefin copolymers obtained with titanium-type catalysts have a broad molecular weight distribution and a broad composition distribution and inferior transparency, surface non-adhesiveness, and mechanical properties. Ethylene/alpha-olefin copolymers obtained with vanadium-type catalysts have a narrower molecular weight distribution and a narrower composition distribution and are considerably improved in transparency, surface non-adhesiveness, and mechanical properties, but are still insufficient for uses which require these properties. Accordingly, alpha-olefin polymers, especially ethylene/alpha-olefin copolymers, improved in these properties are required.

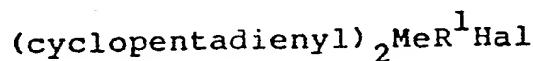
On the other hand, catalysts comprising a

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zirconium compound and an aluminoxane have been proposed recently as a new type of Ziegler catalyst for olefin polymerization.

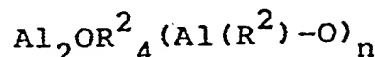
Japanese Laid-Open Patent Publication No.

5 19309/1983 discloses a process which comprises polymerizing ethylene and at least one alpha-olefin having 3 to 12 carbon atoms at a temperature of -50 °C to 200 °C in the presence of a catalyst composed of a transition metal-containing catalyst represented by the following
10 formula



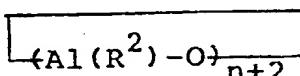
wherein R^1 represents cyclopentadienyl, $\text{C}_1\text{-C}_8$ alkyl or halogen, Me represents a transition metal, and Hal represents halogen,

15 with a linear aluminoxane represented by the following formula



wherein R^2 represents methyl or ethyl, and n is a number of 4 to 20,

20 or a cyclic aluminoxane represented by the following formula



wherein R^2 and n are as defined above.

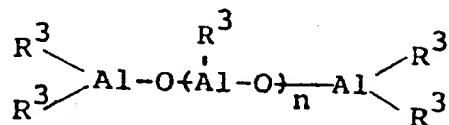
This patent document states that in order to
25 adjust the density of the resulting polyethylene, ethylene should be polymerized in the presence of a small amount (up to 10 % by weight) of a slightly long-chain alpha-olefin or a mixture thereof.

Japanese Laid-Open Patent Publication No.

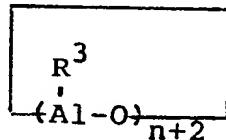
30 95292/1984 describes an invention relating to a process

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for producing a linear aluminoxane represented by the following formula



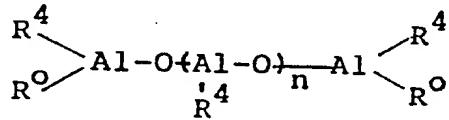
wherein n is 2 to 40 and R^3 is C_1 - C_8 alkyl, and a cyclic aluminoxane represented by the following formula



wherein n and R^3 are as defined above.

This Publication states that when an olefin is polymerized using a mixture of methylaluminoxane produced by the above process with a bis(cyclopentadienyl) compound of titanium or zirconium, polyethylene is obtained in an amount of at least 25 million grams per gram of the transition metal per hour.

Japanese Laid-Open Patent Publication No. 35005/1985 discloses a process for producing a catalyst for polymerization of olefins, which comprises reacting an aluminoxane compound represented by the following formula



wherein R^4 represents C_1 - C_{10} alkyl, and R^O is R^4 or is bonded to represent $-O-$, with a magnesium compound, then chlorinating the reaction product, and treating the chlorinated product with a compound of Ti, V, Zr or Cr. The above Publication describes that the above catalyst is especially suitable

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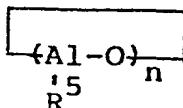
for the copolymerization of ethylene with a C₃-C₁₂ alpha-olefin mixture.

Japanese Laid-Open Patent Publication No. 35006/1985 discloses a combination of (a) a mono-, di- or 5 tri-cyclopentadienyl compound of at least two different transition metals or its derivative with (b) alumoxane (aluminoxane) as a catalyst system for polymers blended in a reactor. Example 1 of this Publication discloses that polyethylene having a number average molecular 10 weight of 15,300 and a weight average molecular weight of 36,400 and containing 3.4 % of a propylene component was obtained by polymerizing ethylene and propylene using bis(pentamethylcyclopentadienyl) dimethyl zirconium and alumoxane as a catalyst. In Example 2 of this Publication, 15 a blend of polyethylene and an ethylene/propylene copolymer having a number average molecular weight of 2,000, a weight average molecular weight of 8,300 and a propylene component content of 7.1 mole % and consisting of a toluene-soluble portion having a number average 20 molecular weight of 2,200, a weight average molecular weight of 11,900 and a propylene component content of 30 mole % and a toluene-insoluble portion having a number average molecular weight of 3,000, a weight average molecular weight of 7,400 and a propylene component 25 content of 4.8 mole % was obtained by polymerizing ethylene and propylene using bis(pentamethylcyclopenta- dienyl)zirconium dichloride, bis(methylcyclopentadienyl)-zirconium dichloride and alumoxane as a catalyst. Likewise, Example 3 of this Publication describes a blend of 30 LLDPE and an ethylene/propylene copolymer composed of a soluble portion having a molecular weight distribution (\bar{M}_w/\bar{M}_n) of 4.57 and a propylene component content of 20.6 mole % and an insoluble portion having a molecular weight distribution of 3.04 and a propylene component content of 35 2.9 mole %.

Japanese Laid-Open Patent Publication No.

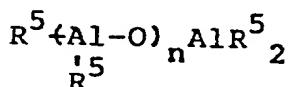
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35007/1985 describes a process which comprises polymerizing ethylene alone or with an alpha-olefin having at least 3 carbon atoms in the presence of a catalyst system comprising metallocene and a cyclic alumoxane represented by the following formula



wherein R^5 represents an alkyl group having 1 to 5 carbon atoms, and n is an integer of 1 to about 20,

10 or a linear alumoxane represented by the following formula



wherein R^5 and n are as defined above.

15 The Publication describes that the polymer obtained by the above process has a weight average molecular weight of about 500 to about 1,400,000 and a molecular weight distribution of 1.5 to 4.0.

Japanese Laid-Open Patent Publication No.

35008/1985 describes that polyethylene or a copolymer of 20 ethylene and a C_3-C_{10} alpha-olefin having a wide molecular weight distribution is produced by using a catalyst system comprising at least two types of metallocenes and alumoxane. The Publication states that the above copolymer has a molecular weight distribution (M_w/M_n) of 25 2 to 50.

These catalysts formed from transition metal compounds and aluminoxanes have much higher polymerization activity than the catalyst systems known heretofore.

30 On the other hand, methods using catalysts formed from solid catalyst components composed of the

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above transition metal compounds supported on porous inorganic oxide carriers such as silica, silica-alumina and alumina and aluminoxanes are proposed in Japanese Laid-Open Patent Publications Nos. 35006/1985, 35007/1985 and 35008/1985 which are cited above. Japanese Laid-Open Patent Publications Nos. 31404/1986, 108610/1986 and 106808/1985 propose methods using solid catalyst components supported on similar porous inorganic oxide carriers.

Furthermore, Japanese Laid-Open Patent Publications Nos. 260602/1985 and 130604/1985 propose a process for polymerizing olefins using catalysts formed from a transition metal compound and a mixed organo-aluminum compound composed of an aluminoxane and an organoaluminum compound.

Japanese Laid-Open Patent Publication No. 260602/1985 discloses a process for producing a poly-olefin by polymerizing an olefin using

(1) as the transition metal compound, a compound of the following formula



wherein Cp is cyclopentadienyl, M is Ti, V, Zr or Hf, and each of R⁶, R⁷ and R⁸ represents C₁-C₆ alkyl, cyclopentadienyl, halogen or hydrogen, and

(2) as the organoaluminum compounds,

(2)-1 an aluminoxane synthesized from a trialkylaluminum and water and

(2)-2 a compound of the following formula



wherein R⁹ is C₁-C₁₀ alkyl, cycloalkyl or aryl, X is halogen, and n is a number of 1 to 3.

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This Laid-Open Patent Publication gives a working example in which ethylene is polymerized in a system comprising 3 millimoles of the aluminoxane, 3 millimoles of triethyl-aluminum and 0.003 millimole of bis(cyclopentadienyl)-zirconium chloride in 400 ml of toluene as a polymerization medium.

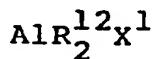
Japanese Laid-Open Patent Publication No. 130604/1985 discloses a process for producing a poly-olefin by polymerizing an olefin using a catalyst composed of, as main components,

(1) a transition metal compound of the following formula



wherein Cp is cyclopentadienyl, M is Ti, Zr or Hf, and each of R¹⁰ and R¹¹ is H, halogen, C₁-C₆ alkyl or cyclopentadienyl,

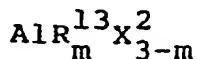
(2) an aluminoxane obtained by reacting a dialkyl monohalide of the formula



wherein R¹² is methyl or ethyl, and X¹ is halogen,

with water, and

(3) an organoaluminum compound represented by the following formula



wherein R¹³ is C₁-C₁₀ alkyl or cycloalkyl, X² is halogen, and m is a number of 1 to 3.

This Laid-Open Patent Publication gives examples of the amounts of the aluminoxane used per 400 ml of toluene as a polymerization medium, 4.5 millimoles (Examples 1-4

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and 8), 3.6 millimoles (Example 5), 3.25 millimoles (Example 6), 10.0 millimoles (Example 7) and 9.0 millimoles (Example 9).

It is an object of this invention to provide a process for producing an alpha-olefin polymer having a narrow molecular weight distribution and a copolymer of alpha-olefins having a narrow molecular weight distribution and a narrow composition distribution when applied to the copolymerization of at least two olefins, especially a high-molecular-weight ethylene/alpha-olefin copolymer having a narrow molecular weight distribution and a narrow composition distribution, with excellent polymerization activity using a small amount of an aluminoxane.

Another object of this invention relates to a process for producing an olefin polymer having excellent powder properties and a narrow molecular weight distribution, and an olefin copolymer having a narrow molecular weight distribution and a narrow composition distribution when applied to the copolymerization of at least two olefins, especially an ethylene polymer or an ethylene/alpha-olefin copolymer having excellent powder properties and a narrow molecular weight distribution and/or a narrow composition distribution.

25 DISCLOSURE OF THE INVENTION

According to this invention, these objects and advantages of this invention are firstly achieved by a process for polymerizing olefins, which comprises polymerizing or copolymerizing olefins in the presence of a catalyst composed of

- (A) a solid catalyst component composed of a compound of a transition metal of Group IVB of the periodic table supported on an inorganic carrier,
- (B) an aluminoxane, and
- (C) an organoaluminum compound having a hydrocarbon group other than n-alkyl groups.

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The catalyst in accordance with this invention is formed of the solid catalyst component (A), the aluminoxane (B) and the organoaluminum compound (C) having a hydrocarbon group other than n-alkyl groups.

5 The catalyst component (A) is a solid catalyst component composed of a carrier and a compound of a transition metal of Group IVB of the periodic table supported on it.

The transition metal of Group IVB of the periodic table in the catalyst component (A) is preferably selected from the group consisting of titanium, zirconium and hafnium. Titanium and zirconium are more preferred, and zirconium is especially preferred.

10 The compound of a transition metal of Group IVB of the periodic table in the catalyst component (A) preferably has a group with a conjugated π -electron as a ligand.

15 Examples of the transition metal compound having a group with a conjugated π -electron as a ligand are compounds represented by the following formula (I)



wherein R^1 represents a cycloalkadienyl group, R^2 , R^3 and R^4 are identical or different and each represents a cycloalkadienyl group, an aryl group, an alkyl group, a cycloalkyl group, an aralkyl group, a halogen atom, a 25 hydrogen atom, or a group of the formula $-OR^a$, $-SR^b$ or $-NR_2^c$ in which each of R^a , R^b and R^c represents an alkyl group, a cycloalkyl group, an aryl group, an aralkyl group or an organic silyl group, Me represents zirconium, titanium or hafnium, k is 1, 2, 3 or 4, ℓ , m and n are 30 each 0, 1, 2 or 3, and $k+\ell+m+n=4$.

Examples of the cycloalkadienyl group represented by R^1 are a cyclopentadienyl group, a methyl-cyclopentadienyl group, an ethylcyclopentadienyl group, a

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dimethylcyclopentadienyl group, an indenyl group and a tetrahydroindenyl group. Examples of the cycloalkadienyl group represented by R^2 , R^3 and R^4 may be the same as above.

5 The aryl group represented by R^2 , R^3 and R^4 is preferably a phenyl or tolyl group, for example.

Likewise, preferred examples of the aralkyl group are benzyl and neophile groups.

10 Examples of preferred alkyl groups are methyl, ethyl, propyl, isopropyl, butyl, hexyl, octyl, 2-ethylhexyl, decyl and oleyl groups.

Preferably, the cycloalkyl group may be, for example, a cyclopentyl, cyclohexyl, cyclooctyl, or norbornyl group.

15 The halogen atom may be, for example, fluorine, chlorine or bromine.

Specific examples of the groups $-OR^a$, $-SR^b$ and $-NR_2^C$ where R^a , R^b and R^C are alkyl, cycloalkyl, aryl and aralkyl will be clear from the above specific examples of 20 these groups.

Examples of the organic silyl group for R^a , R^b and R^C are trimethylsilyl, triethylsilyl, phenyldimethylsilyl, diphenylmethylysilyl and triphenylsilyl groups.

25 Examples of zirconium compounds corresponding to formula (I) in which Me is zirconium are listed below.

bis(Cyclopentadienyl)zirconium monochloride monohydride,

bis(cyclopentadienyl)zirconium monobromide monohydride,

30 bis(cyclopentadienyl)methylzirconium hydride, bis(cyclopentadienyl)ethylzirconium hydride, bis(cyclopentadienyl)cyclohexylzirconium hydride,

35 bis(cyclopentadienyl)phenylzirconium hydride, bis(cyclopentadienyl)benzylzirconium hydride, bis(cyclopentadienyl)neopentylzirconium hydride,

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bis(methylcyclopentadienyl)zirconium mono-
chloride monohydrate,
bis(indenyl)zirconium monochloride monohydrate,
bis(cyclopentadienyl)zirconium dichloride,
5 bis(cyclopentadienyl)zirconium dibromide,
bis(cyclopentadienyl)methylzirconium mono-
chloride,
bis(cyclopentadienyl)ethylzirconium mono-
chloride,
10 bis(cyclopentadienyl)cyclohexylzirconium mono-
chloride,
bis(cyclopentadienyl)phenylzirconium mono-
chloride,
bis(cyclopentadienyl)benzylzirconium mono-
chloride,
15 bis(methylcyclopentadienyl)zirconium di-
chloride,
bis(indenyl)zirconium dichloride,
bis(indenyl)zirconium dibromide,
20 bis(cyclopentadienyl)diphenylzirconium,
bis(cyclopentadienyl)dibenzylzirconium,
bis(cyclopentadienyl)methoxyzirconium chloride,
bis(cyclopentadienyl)ethoxyzirconium chloride,
bis(cyclopentadienyl)butoxyzirconium chloride,
25 bis(cyclopentadienyl)2-ethylhexoxyzirconium
chloride,
bis(cyclopentadienyl)methylzirconium ethoxide,
bis(cyclopentadienyl)methylzirconium butoxide,
bis(cyclopentadienyl)ethylzirconium ethoxide,
30 bis(cyclopentadienyl)phenylzirconium ethoxide,
bis(cyclopentadienyl)benzylzirconium ethoxide,
bis(methylcyclopentadienyl)ethoxyzirconium
chloride,
bis(indenyl)ethoxyzirconium chloride,
35 bis(cyclopentadienyl)ethoxyzirconium,
bis(cyclopentadienyl)butoxyzirconium,

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bis(cyclopentadienyl)2-ethylhexoxozirconium,
bis(cyclopentadienyl)phenoxyzirconium chloride,
bis(cyclopentadienyl)cyclohexoxozirconium
chloride,
5 bis(cyclopentadienyl)phenylmethoxozirconium
chloride,
bis(cyclopentadienyl)methylzirconium phenyl-
methoxide,
bis(cyclopentadienyl)trimethylsiloxyzirconium
10 chloride,
bis(cyclopentadienyl)triphenylsiloxyzirconium
chloride,
bis(cyclopentadienyl)thiophenylzirconium
chloride,
15 bis(cyclopentadienyl)thioethylzirconium
chloride,
bis(cyclopentadienyl)bis(dimethylamide)-
zirconium,
bis(cyclopentadienyl)diethylamidezirconium
20 chloride,
ethylenebis(indenyl)ethoxozirconium chloride,
ethylenebis(4,5,6,7-tetrahydro-1-indenyl)-
ethoxozirconium chloride,
ethylenebis(indenyl)dimethylzirconium,
25 ethylenebis(indenyl)diethylzirconium,
ethylenebis(indenyl)dibenzylzirconium,
ethylenebis(indenyl)methylzirconium mono-
bromide,
ethylenebis(indenyl)ethylzirconium mono-
30 chloride,
ethylenebis(indenyl)benzylzirconium mono-
chloride,
ethylenebis(indenyl)methylzirconium mono-
chloride,
35 ethylenebis(indenyl)zirconium dichloride,
ethylenebis(indenyl)zirconium dibromide,

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ethylenebis(4,5,6,7-tetrahydro-1-indenyl)dimethylzirconium,
ethylenebis(4,5,6,7-tetrahydro-1-indenyl)-
methylzirconium monochloride,
5 ethylenebis(4,5,6,7-tetrahydro-1-indenyl)-
zirconium dichloride,
ethylenebis(4,5,6,7-tetrahydro-1-indenyl)-
zirconium dibromide,
ethylenebis(4-methyl-1-indenyl)zirconium di-
10 chloride,
ethylenebis(5-methyl-1-indenyl)zirconium di-
chloride,
ethylenebis(6-methyl-1-indenyl)zirconium di-
chloride,
15 ethylenebis(7-methyl-1-indenyl)zirconium di-
chloride,
ethylenebis(5-methoxy-1-indenyl)zirconium
dichloride,
ethylenebis(2,3-dimethyl-1-indenyl)zirconium
20 dichloride,
ethylenebis(4,7-dimethyl-1-indenyl)zirconium
dichloride,
ethylenebis(4,7-dimethoxy-1-indenyl)zirconium
dichloride,
25 ethylenebis(indenyl)zirconium dimethoxide,
ethylenebis(indenyl)zirconium diethoxide,
ethylenebis(indenyl)methoxyzirconium chloride,
ethylenebis(indenyl)ethoxyzirconium chloride,
ethylenebis(indenyl)methylzirconium ethoxide,
30 ethylenebis(4,5,6,7-tetrahydro-1-indenyl)-
zirconium dimethoxide,
ethylenebis(4,5,6,7-tetrahydro-1-indenyl)-
zirconium diethoxide,
ethylenebis(4,5,6,7-tetrahydro-1-indenyl)-
35 methoxyzirconium chloride,
ethylenebis(4,5,6,7-tetrahydro-1-indenyl)-
ethoxyzirconium chloride, and

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ethylenebis(4,5,6,7-tetrahydro-1-indenyl)methyl-zirconium ethoxide.

Examples of titanium compounds corresponding to formula (I) in which Me is titanium are listed below.

5 bis(Cyclopentadienyl)titanium monochloride monohydrate,

10 bis(cyclopentadienyl)methyltitanium hydride,
bis(cyclopentadienyl)phenyltitanium chloride,
bis(cyclopentadienyl)benzyltitanium chloride,
bis(cyclopentadienyl)titanium chloride,
bis(cyclopentadienyl)dibenzyltitanium,
bis(cyclopentadienyl)ethoxytitanium chloride,
bis(cyclopentadienyl)butoxytitanium chloride,
bis(cyclopentadienyl)methyltitanium ethoxide,
15 bis(cyclopentadienyl)phenoxytitanium chloride,
bis(cyclopentadienyl)trimethylsiloxytitanium
chloride,

20 bis(cyclopentadienyl)thiophenyltitanium
chloride,

25 bis(cyclopentadienyl)bis(dimethylamide)-
titanium,

30 bis(cyclopentadienyl)ethoxytitanium,
ethylenebis(indenyl)titanium dichloride, and
ethylenebis(4,5,6,7-tetrahydro-1-indenyl)-
titanium dichloride.

Examples of hafnium compounds corresponding to formula (I) in which Me is hafnium are listed below.

35 bis(Cyclopentadienyl)hafnium monochloride
monohydrate,

30 bis(cyclopentadienyl)ethylhafnium hydride,
bis(cyclopentadienyl)phenylhafnium chloride,
bis(cyclopentadienyl)hafnium dichloride,
bis(cyclopentadienyl)dibenzylhafnium,
bis(cyclopentadienyl)ethoxyhafnium chloride,
bis(cyclopentadienyl)butoxyhafnium chloride,
bis(cyclopentadienyl)methylhafnium ethoxide,

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bis(cyclopentadienyl)phenoxyhafnium chloride,
bis(cyclopentadienyl)thiophenylhafnium
chloride,

5 bis(cyclopentadienyl)bis(diethylamide)hafnium,
ethylenebis(indenyl)hafnium dichloride, and
ethylenebis(4,5,6,7-tetrahydro-1-indenyl)-
hafnium dichloride.

In the catalyst component (A), the IVB transition metal compound may be treated with an organic metal compound or a halogen-containing silicon compound prior to deposition. The organic metal compound may be, for example, an organoaluminum compound, an organoboron compound, an organomagnesium compound, an organozinc compound or an organolithium compound. The organo-
aluminum compound is preferred.

Examples of the organoaluminum compound include trialkylaluminums such as trimethylaluminum, triethylaluminum and tributylaluminum; alkenylaluminums such as isoprenylaluminum; dialkyl aluminum alkoxides such as 20 dimethyl aluminum methoxide, diethyl aluminum ethoxide and dibutyl aluminum butoxide; alkyl aluminum sesquialkoxydes such as methyl aluminum sesquimethoxide and ethyl aluminum sesquiethoxide; partially alkoxylated alkylaluminums having an average composition of the 25 formula $R_2.5^{1} Al(OR^2)^{0.5}$; dialkyl aluminum halides such as dimethyl aluminum chloride, diethyl aluminum chloride and dimethyl aluminum bromide; alkyl aluminum sesquihalides such as methyl aluminum sesquichloride and ethyl aluminum sesquichloride; partially halogenated alkylaluminums, for 30 example alkyl aluminum dihalides such as methyl aluminum dichloride and ethyl aluminum dichloride.

The trialkylaluminums and dialkyl aluminum chlorides are preferred, and above all trimethylaluminum, triethylaluminum and dimethyl aluminum chloride are preferred.

Triethylboron is a preferred example of the organoboron compound.

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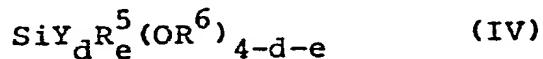
Examples of the organomagnesium compound are ethylbutylmagnesium, di-n-hexylmagnesium, ethyl magnesium bromide, phenyl magnesium bromide and benzyl magnesium chloride.

5 Diethylzinc is a preferred example of the organozinc compound.

Methylolithium, butyllithium and phenyllithium are examples of the organolithium compound.

10 An organoaluminum compound is preferred as the organic metal compound (C).

As the halogen-containing silicon compound as a treating agent, compounds of the following formula (IV)



15 wherein Y is a chlorine or bromine atom, R⁵ and R⁶, independently from each other, represent an alkyl group having 1 to 12 carbon atoms, an aryl group, or a cycloalkyl group having 3 to 12 carbon atoms, d is a number of 1 to 4 and e is a number of 0 to 4, provided that the sum of d and e is a number of 1 to 4,
20 are preferably used.

Examples of such compounds include silicon tetrachloride, silicon tetrabromide, silicon trichloride, methylsilicon trichloride, ethylsilicon trichloride, 25 propylsilicon trichloride, phenylsilicon trichloride, cyclohexylsilicon trichloride, silicon tribromide, ethylsilicon tribromide, dimethylsilicon dichloride, methylsilicon dichloride, phenylsilicon dichloride, methoxy-silicon trichloride, ethoxysilicon trichloride, propoxy-silicon trichloride, phenoxy-silicon trichloride, ethoxy-silicon tribromide, methoxysilicon dichloride, di-methoxysilicon dichloride, and silanol trichloride. These compounds may be used singly or in combination. Among them, silicon tetrachloride, silicon trichloride

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and methylsilicon trichloride are preferred.

The mixing ratio of the organometallic compound to the inorganic carrier in the above treatment, as the ratio of the amount of the organometallic compound in 5 millimoles/the amount of the carrier in grams, is from 0.5 to 50, preferably from 1 to 30, more preferably from 1.5 to 20.

The treatment of the inorganic carrier with the organometallic compound in the preparation of the catalyst component (A) can be carried out by dispersing the carrier in an inert solvent, adding at least one of the 10 above-described organometallic compounds, and treating the carrier at a temperature of 0 to 120 °C, preferably 10 to 100 °C, more preferably 20 to 90 °C, for a period 15 of 10 minutes to 10 hours, preferably 20 minutes to 5 hours, more preferably 30 minutes to 3 hours, under reduced or elevated pressure.

Examples of the inert solvent are aromatic hydrocarbons such as benzene, toluene and xylene, 20 aliphatic hydrocarbons such as pentane, hexane and isooctane and alicyclic hydrocarbons such as cyclohexane.

In the above-treatment, the mixing ratio of the inorganic carrier to the halogen-containing silicon compound, is such that the halogen-containing silicon 25 compound is used in an amount of 0.001 to 10 moles, preferably 0.01 to 50 moles, more preferably 0.05 to 1 mole, per gram of the carrier compound. Preferably, after the above treatment, the liquid portion containing the excess of the halogen-containing silane compound, 30 etc. is removed from the reaction mixture by such a method as filtration or decantation.

The treatment of the inorganic carrier with the halogen-containing silicon compound in preparing the catalyst component (A) may be carried out at a temperature of -50 to 200 °C, preferably 0 to 100 °C, more 35 preferably 20 to 70 °C, for a period of 10 minutes to

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10 hours, preferably 20 minutes to 5 hours, under atmospheric, reduced or elevated pressure.

An inert solvent may be used in the above treatment. Examples of the inert solvent include 5 aromatic hydrocarbons such as benzene, toluene and xylene, aliphatic hydrocarbons such as pentane, hexane, iso-octane, decane and dodecane, alicyclic hydrocarbons such as cyclohexane and halogenated hydrocarbons such as chlorobenzene and ethylene dichloride.

10 In the deposition of the Group IVB transition metal compound on the inorganic carrier in the preparation of the catalyst component (A), an inert solvent needs not to be used when the transition metal compound is a liquid substance. If the transition metal compound 15 is a solid substance at ordinary temperature, it is preferred generally to use an inert solvent capable of dissolving the transition metal compound.

The inert solvent used at this time may be the same inert solvent as that used in treating the inorganic 20 carrier with the halogen-containing silicon compound. Aromatic hydrocarbons such as benzene and toluene and halogenated hydrocarbons such as chlorobenzene are especially preferred.

The amount of the transition metal compound 25 used in the above supporting reaction is preferably 0.001 to 500 millimoles, more preferably 0.01 to 100 millimoles, especially preferably 0.1 to 50 millimoles, per gram of the inorganic carrier.

The amount of the inert solvent used in the 30 above supporting reaction is preferably 0.5 to 1000 ml, more preferably 1 to 100 ml, especially preferably 2 to 50 ml, per gram of the inorganic carrier treated with the halogen-containing silane compound.

The above supporting reaction can be carried 35 out by contacting and mixing the inorganic carrier and the transition metal compound at a temperature of 0 to

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200 °C, preferably 0 to 100 °C, especially preferably 20 to 80 °C, for a period of 1 minute to 10 hours, 5 minutes to 5 hours, 10 minutes to 3 hours.

5 After the supporting reaction by the above method, it is preferred to remove the liquid portion of the reaction mixture by such a method as filtration or decantation and wash the residue several times with an inert solvent.

10 In the catalyst of this invention, the solid catalyst component (A) is obtained by supporting the compound of a transition metal of Group IVB of the periodic table on the carrier.

15 The inorganic carrier is advantageously a granular or fine particulate solid having a particle diameter of, for example, 10 to 300 micrometers, preferably 20 to 200 micrometers. Preferably, it is a porous oxide. Specific examples include SiO_2 , Al_2O_3 , MgO , ZrO_2 , TiO_2 , B_2O_3 , CaO , ZnO , BaO , ThO_2 and mixtures of these such as $\text{SiO}_2\text{-MgO}$, $\text{SiO}_2\text{-Al}_2\text{O}_3$, $\text{SiO}_2\text{-TiO}_2$, $20 \text{SiO}_2\text{-V}_2\text{O}_5$, $\text{SiO}_2\text{-Cr}_2\text{O}_3$ and $\text{SiO}_2\text{-TiO}_2\text{-MgO}$. Carriers containing at least one component selected from the group consisting of SiO_2 and Al_2O_3 as a main component are preferred.

25 The inorganic oxides may contain small amounts of carbonates, sulfates, nitrates or oxide components such as Na_2CO_3 , K_2CO_3 , CaCO_3 , MgCO_3 , Na_2SO_4 , $\text{Al}_2(\text{SO}_4)_3$, BaSO_4 , KNO_3 , $\text{Mg}(\text{NO}_3)_2$, $\text{Al}(\text{NO}_3)_3$, Na_2O , K_2O and Li_2O .

30 The porous inorganic carrier have different properties depending upon its type and the method of production. Carriers preferably used in this invention have a specific surface area of 50 to 1000 m^2/g , preferably 100 to 700 m^2/g and a pore volume of 0.3 to 2.5 cm^2/g . The above carrier is used after it is calcined at a temperature of usually 150 to 1000 °C, preferably 200 to 800 °C.

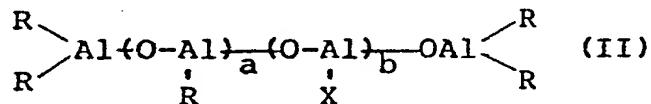
35 In the catalyst component (A) in this

- 20 -

invention, the compound of the transition metal of Group IVB of the periodic table is supported in an amount of 3×10^{-3} to 3 milligram-atoms, preferably 5×10^{-3} to 2 milligram-atoms, more preferably 1×10^{-2} to 1 milligram-atom, as the transition metal atom, per gram of the inorganic carrier treated with the organometallic compound.

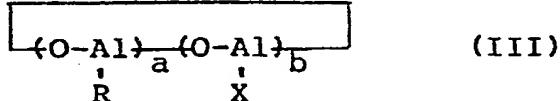
The catalyst component (A) contains the transition metal compound in an amount of usually 0.005 millimole to 5 millimoles, preferably 0.01 millimole to 1 millimole, especially preferably 0.03 millimole to 0.3 millimole, per gram of the inorganic carrier treated with the halogen-containing silicon compound.

The catalyst component (B) is an aluminoxane. The aluminoxane used as the catalyst component is, for example, an organoaluminum compound of the following formula (II)



wherein R is a hydrocarbon group, X is a halogen atom, and a and b, independently from each other, represent a number of 0 to 80 with the proviso that a and b are not simultaneously zero (in this formula, the degree of polymerization is $a+b+2$),

or the following formula (III)



wherein R, X, a and b are as defined hereinabove with regard to formula (II) (in this

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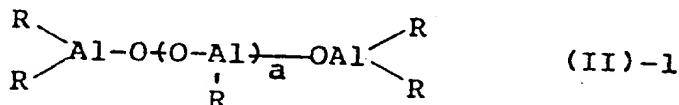
formula, the degree of polymerization is $a+b$).

In formulae (II) and (III), R represents a hydrocarbon group such as an alkyl, cycloalkyl, aryl or aralkyl group. Preferred as the alkyl group are lower alkyl groups such as a methyl, ethyl, propyl or butyl group. Cyclopentyl and cyclohexyl groups are preferred examples of the cycloalkyl group. Preferred aryl groups are, for example, phenyl and tolyl groups. Preferably, the aralkyl group is, for example, a benzyl or neophile group. Of these, the alkyl groups are especially preferred.

X is a halogen atom such as fluorine, chlorine, bromine and iodine. Chlorine is especially preferred.

a and b, independently from each other, are numbers of 0 to 80, with the proviso that a and b are not simultaneously zero.

When b is 0, formula (II) may be written as the following formula (II)-1



wherein R and a are as defined above, and formula (III) may be written as the following formula (III)-1



wherein R and a are as defined above.

In formula (II)-1, a is preferably 2 to 50, more preferably 4 to 30. Furthermore, in formula (III)-1, a is preferably 4 to 52, more preferably 6 to 32.

a is preferably 0 to 40, more preferably 3 to 30, and b is preferably 1 to 40, more preferably 3 to 30.

The value of $a+b$ is preferably 4 to 50, more preferably 8 to 30.

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In formulae (II) and (III), the two units -O-Al- and -O-Al- may be bonded in blocks or at random.

• R

When a is 0 in formulae (II) and (III), it is desirable to use an organoaluminum compound of the following formula (V)



wherein R^7 is an alkyl group having 1 to 10 carbon atoms or a cycloalkyl group having 3 to 12 carbon atoms, Z is a halogen atom, and f is a number of 1 to 3,

10 together with the halogenated aluminoxane. Examples of such an organoaluminum compound include trimethylaluminum, triethylaluminum, tributylaluminum trihexylaluminum, diethylaluminum chloride and ethylaluminum
15 sesquichloride.

Preferably, the halogenated aluminoxane and the organoaluminum compound are used at this time such that the amount of the organoaluminum compound is 0.1 to 10 moles, preferably 0.3 to 3.0 moles, especially preferably 0.5 to 2.0 mole, per mole of Al atom in the halogenated aluminoxane.

The aluminoxane or the halogenated aluminoxane described above can be produced, for example, by the following methods.

25 (1) A method which comprises suspending a compound containing water of adsorption or a salt containing water of crystallization, such as magnesium chloride hydrate, nickel sulfate hydrate or cerous chloride hydrate in a medium such as benzene, toluene,
30 ethyl ether or tetrahydrofuran, and reacting it with a trialkylaluminum and/or a dialkylaluminum monohalide.

(2) A method which comprises reacting a trialkylaluminum and/or a dialkylaluminum monohalide

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directly with water in a medium such as benzene, toluene, ethyl ether or tetrahydrofuran.

It is preferred to adopt the method (1).

Incidentally, the aluminoxane may contain a small amount 5 of an organometallic compound.

Then catalyst component (C) is an organo-aluminum compound having a hydrocarbon group other than n-alkyl groups. Such a hydrocarbon group may be, for example, an alkyl group having a branched chain such as 10 an iso-alkyl group, a cycloalkyl group and an aryl group. Examples of the above organoaluminum compound are tri-alkylaluminums such as triisopropylaluminum, triiso-butylaluminum, tri-2-methylbutylaluminum, tri-3-methylbutylaluminum, tri-2-methylpentylaluminum, tri-3-methylpentylaluminum, tri-4-methylpentylaluminum, tri-2-methylhexylaluminum, tri-3-methylhexylaluminum and 15 tri-2-ethylhexylaluminum; tricycloalkylaluminums such as tricyclohexylaluminum; triarylaluminums such as tri-phenylaluminum and tritolylaluminum; dialkylaluminum hydrides such as diisobutylaluminum hydride; and alkyl-aluminum alkoxides such as isobutylaluminum methoxide, isobutylaluminum ethoxide and isobutylaluminum iso-propoxide. Of these organoaluminum compounds, organo-aluminum compounds having a branched alkyl group are 20 preferred, and the trialkylaluminums are especially preferred. Furthermore, isoprenylaluminums having the general formula $(i-C_4C_9)_xAl_y(C_5H_{10})_z$ wherein x, y and z are positive numbers and $z \geq 2x$ are also preferably used. There can also be used compounds which will yield the 25 above organoaluminum compounds in the polymerization system, for example a combination of an aluminum halide and an alkylolithium or a combination of an aluminum halide and an alkylmagnesium, may also be used.

In the process of this invention, the polymerization 30 of olefins may be carried out by a liquid-phase polymerization method (e.g., slurry polymerization

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or solution polymerization) or a gas-phase polymerization method. Prior to the olefin polymerization, prepolymerization may be carried out using a small amount of an olefin.

5 The prepolymerization is carried out (1) in the absence of solvent, or (2) in an inert hydrocarbon medium. Of these, the method (1) is preferred. Desirably, at this time, the catalyst components (A) and (B) are mixed in an inert hydrocarbon medium, and the solvent 10 is removed by using an evaporator at room temperature or an elevated temperature under atmospheric or reduced pressure. The mole ratio of the transition metal atom in catalyst component (A) to the aluminum atom in catalyst component (B) in the prepolymerization treatment (Al/the 15 transition metal atom) is from 20 to 5000, preferably from 25 to 2000, more preferably from 30 to 1000. The prepolymerization temperature is from -20 °C to 70 °C, preferably -10 °C to 60 °C, more preferably 0 °C to 50 °C.

20 The treatment may be carried out either batch-wise or continuously under reduced, atmospheric or elevated pressure. The prepolymerization may be carried out in the presence of a molecular weight controlling agent such as hydrogen, but it is preferred to limit its 25 amount at least to one sufficient to produce a prepolymer having an intrinsic viscosity $[\eta]$, measured in decalin at 135 °C, of at least 0.2 dl/g, preferably 0.5 to 20 dl/g.

30 The amount of the transition metal compound (A) at the time of performing the process of this invention by the slurry polymerization technique or the gas-phase polymerization technique is, in terms of the concentration of the transition metal atom in the polymerization reaction system, 10^{-8} to 10^{-2} gram-atom/liter, preferably 10^{-7} to 10^{-3} gram-atom/liter.

35 In the process of this invention, the amount of the aluminoxane (B), calculated as the aluminum atom in

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the reaction system, is not more than 3 milligram-atoms/liter, preferably 0.1 to 2.5 milligram-atoms/liter, especially preferably 0.2 to 2 milligram-atoms/liter. The proportion of the aluminum atoms of the aluminoxane 5 component (B) based on the total amount of the aluminum atoms in the aluminoxane component (B) and the organo-aluminum compound component (C) is usually 20 to 80 %, preferably 25 to 75 mole %, and especially preferably 30 to 70 %. Corresponding to this amount, the proportion of 10 the aluminum atom in the organoaluminum compound component (C) is usually 20 to 80 %, preferably 25 to 75 %, especially preferably 30 to 70 %. In the process of this invention, the ratio of the total amount of aluminum atoms in the aluminoxane component (B) and the organo-aluminum compound component (C) to the transition metal 15 atom in the reaction system is usually from 20 to 10000, preferably from 50 to 5000, especially preferably from 100 to 2000.

According to the above catalyst in accordance 20 with this invention, olefins can be polymerized or co-polymerized advantageously.

Investigations of the present inventors have shown that when a compound of a transition metal of group IV of the periodic table and containing a ligand having a 25 conjugated π -electron and a ligand containing hetero atom capable of being bonded to the transition metal and selected from the group consisting of oxygen, sulfur, nitrogen and phosphorus is used as the transition metal compound in the catalyst system, the resulting compound 30 shows the same excellent activity as the catalyst system composed of the components (A), (B) and (C) even if it is not supported on the inorganic carrier.

Accordingly, the present invention secondly provides a process for producing olefins, which comprises 35 polymerizing or copolymerizing the olefins in the presence of a catalyst composed of

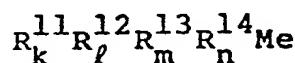
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(A)' a compound of a transition metal of Group IV of the periodic table containing a ligand having a conjugated π -electron and a ligand containing a hetero atom capable of being bonded to the transition metal and 5 selected from the group consisting of oxygen, sulfur, nitrogen and phosphorus,

(B) an aluminoxane, and

(c) an organoaluminum compound having a hydrocarbon group other than n-alkyl groups.

10 For example, the transition metal compound (A)' may preferably be a compound of the following formula (I)'



15 wherein R^{11} is cycloalkadienyl, R^{12} is selected from the class consisting of $-OR^a$, $-SR^b$, $-NR_2^c$ and $-PR_2^d$, R^{13} and R^{14} , independently from each other, represent cycloalkadienyl, aryl, aralkyl, halogen or hydrogen, R^a , R^b and R^c represent 20 alkyl, cycloalkyl, aryl, aralkyl or organic silyl, Me is zirconium, titanium, or hafnium, k and ℓ are 1, 2 or 3, m and n are 0, 1 or 2 and $k+\ell+m+n=4$.

Examples of the compounds of formula (I)' include zirconium compounds such as

25 bis(cyclopentadienyl)methoxyzirconium chloride, bis(cyclopentadienyl)ethoxyzirconium chloride, bis(cyclopentadienyl)butoxyzirconium chloride, bis(cyclopentadienyl)2-ethylhexoxyzirconium chloride,

30 bis(cyclopentadienyl)methylzirconium ethoxide, bis(cyclopentadienyl)methylzirconium butoxide, bis(cyclopentadienyl)ethylzirconium ethoxide, bis(cyclopentadienyl)phenylzirconium ethoxide, bis(cyclopentadienyl)benzylzirconium ethoxide, 35 bis(methylcyclopentadienyl)ethoxyzirconium chloride,

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bis(cyclopentadienyl)ethoxytitanium; and hafnium compounds such as

5 bis(cyclopentadienyl)ethoxyhafnium chloride,
bis(cyclopentadienyl)butoxyhafnium chloride,
bis(cyclopentadienyl)methylhafnium ethoxide,
bis(cyclopentadienyl)phenoxyhafnium chloride,
bis(cyclopentadienyl)thiophenylhafnium
chloride, and

10 It should be understood that in the process of this invention using the above catalyst system composed of the catalyst components (A)', (B) and (C), the preferred concentrations and proportions of these catalyst components (A)', (B) and (C) are the same as described 15 hereinabove with the aforesaid catalyst system.

Investigations of the present inventors have also shown that by limiting the amount of the aluminoxane used to not more than 3 milligram-atoms/liter as Al atom in the catalyst system composed of the components (A), (B) and (C) and the catalyst system composed of (A)', (B) and (C), excellent catalytic activity can be exhibited.

On the basis of this fact, it has been found that when the amount of the aluminoxane used is limited to not more than 3 milligram-atoms/liter as Al atom in the reaction system, the use of any of the compounds of formula (I) as the group IVB transition metal compounds without being supported on the inorgnaic carrier can exhibit the same excellent activity.

Accordingly, the present invention thirdly provides a process for polymerizing or copolymerizing olefins in the presence of a catalyst composed of (A)" a compound of a transition metal of Group IVB of the periodic table,

(B) an aluminoxane in a concentration of not
35 more than 3 milligrams/liter as aluminum atom in the
reaction system, and

- 29 -

(C) an organoaluminum compounds having a hydrocarbon group other than n-alkyl groups.

The same compounds as represented by formula (I) can be used as the transition metal compound (A)".

5 The alumionoxane (B) and the organoaluminum compound (C) may be the same as described above.

In the process of this invention, the catalyst components (A)", (B) and (C) may be separately fed into the reaction system. Or it is possible to add a pre-mixture of any two of the above compounds and the remaining one catalyst component separately into the reaction system. Alternatively, all the catalyst components may be pre-mixed and then fed into the reaction system. When two catalyst components are to be mixed in 15 advance, the catalyst components to be mixed are preferably the catalyst components (A) and (B).

In the premixing of the catalyst components (A) and (B), the concentration of the transition metal atom is usually 2.5×10^{-4} to 1.5×10^{-1} gram-atom/liter, 20 preferably 5.0×10^{-4} to 1.0×10^{-1} gram-atom/liter. The concentration of the aluminoxane is usually 0.05 to 5 gram-atoms/liter, preferably 0.1 to 3 gram-atoms/liter, as Al atom. The temperature in the premixing is usually -50 °C to 100 °C, and the mixing time is usually 0.1 25 minute to 50 hours.

It should be understood that the preferred concentrations and mixing ratios of the components (A)", (B) and (C) in the polymerization system are the same as in the above catalyst system.

30 All the catalysts described above can be used advantageously in the homopolymerization or copolymerization of olefins. They are especially effective for the production of an ethylene polymer and ethylene/alpha-olefin copolymers. Examples of the olefins that can be 35 utilized are ethylene and alpha-olefins having 3 to 20 carbon atoms, such as propylene, 1-butene, 1-hexene,

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4-methyl-1-pentene, 1-octene, 1-decene, 1-dodecene, 1-tetradecene, 1-hexadecene, 1-octadecene and 1-eicocene.

The polymerization of olefins by the process of this invention is usually carried out in a gas-phase or 5 in a liquid phase, for example in slurry. In the slurry polymerization, an inert hydrocarbon may be used as a solvent. It is also possible to use an olefin itself as the solvent.

Specific examples of the hydrocarbon solvent 10 are aliphatic hydrocarbons such as butane, isobutane, pentane, hexane, octane, decane, dodecane, hexadecane and octadecane; alicyclic hydrocarbons such as cyclopentane, methylcyclopentane, cyclohexane and cyclooctane, aromatic hydrocarbons such as benzene, toluene and xylene, and 15 petroleum fractions such as gasoline, kerosene and light oil. Of these hydrocarbon media, the aliphatic hydrocarbons, alicyclic hydrocarbons and petroleum fractions are preferred.

When slurry polymerization is carried out in 20 the process of this invention, the polymerization temperature is usually -50 to 120 °C, preferably 0 to 100 °C.

When slurry polymerization or gas-phase polymerization is carried out by the process of this 25 invention, the proportion of the transition metal compound is usually 10^{-8} to 10^{-2} gram-atom/liter, preferably 10^{-7} to 10^{-3} gram-atom/liter as the transition metal atom in the polymerization system.

In the present polymerization reaction, the 30 aluminoxane may, or may not, be used additionally. To obtain a polymer having excellent powder properties, it is preferred not to use the aluminoxane additionally.

The polymerization pressure is usually atmospheric pressure to 100 kg/cm², preferably 2 to 50 kg/cm². 35 The polymerization may be carried out batchwise, semi-continuously or continuously.

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The polymerization may be carried out in two or more stages having different reaction conditions.

When the slurry polymerization method or the gas-phase polymerization method is used to polymerize 5 olefins, particularly polymeric ethylene or ethylene with an alpha-olefin in this invention, there is no polymer adhesion to the reactor and the resulting polymer has excellent powder properties and a narrow molecular weight distribution. When the invention is applied to the 10 copolymerization of at least two olefins, an olefin copolymer having a narrow molecular weight distribution and a narrow composition distribution can be obtained.

[EXAMPLES]

The process of this invention will now be 15 specifically illustrated by the following examples. The \bar{M}_w/\bar{M}_n value was measured by the following procedure in accordance with Takeuchi, "Gel Permeation Chromatography", published by Maruzen Co., Ltd.

(1) By using standard polystyrene of a known 20 molecular weight (monodisperse polystyrene produced by Toyo Soda Co., Ltd.), the molecular weight M and its GPC (gel permeation chromatograph) count are measured. A calibration curve of the molecular weight M versus EV (elution volume) is prepared. The concentration at this 25 time is adjusted to 0.02 % by weight.

(2) The GPC chromatogram of the sample is taken by GPC, and the number average molecular weight \bar{M}_n and the weight average molecular weight \bar{M}_w of the sample are calculated as polyethylene by the procedure (1) 30 above, and the \bar{M}_w/\bar{M}_n value is determined. The sample preparation conditions and the GPC measurement conditions at this time are as follows:-

Sample preparation:

(a) Take the sample together with o-dichloro- 35 benzene solvent in an Erlenmeyer flask so that its concentration is 0.1 % by weight.

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(b) Heat the flask to 140 °C and stir the contents for about 30 minutes to dissolve the sample.

(c) Subject the filtrate from it to GPC.

GPC measurement conditions:

5 (a) Device: 150C-ALC/GPC made by Waters Co.
(b) Column: GMH type made by Toyo Soda Co.,
Ltd.

(c) Amount of the sample: 400 microliters

(d) Temperature: 140 °C

10 (e) Flow rate: 1 ml/min.

The amount of an n-decane-soluble portion in the copolymer (as the amount of the soluble portion is smaller, the narrow is the composition distribution) was measured by adding about 3 g of the copolymer to 450 ml 15 of n-decane, dissolving the copolymer at 145 °C, cooling the solution to 23 °C, removing the n-decane-insoluble portion by filtration, and recovering the n-decane-soluble portion from the filtrate.

The B value of the ethylenic copolymer of this 20 invention is defined as follows:

$$B = \frac{P_{OE}}{2P_O \cdot P_E}$$

25 wherein P_E represents the molar fraction of the ethylene component in the copolymer, P_O represents the molar fraction of the alpha-olefin component, and P_{OE} represents the molar fraction of the alpha-olefin/ethylene sequence in the total dyad sequence.

The B value is an index showing the state of distribution of the individual monomer components in the 30 copolymer and is calculated by determining P_E , P_O and P_{OE} in the above definition in accordance with the papers of G. J. Ray [Macromolecules, 10, 773 (1977)], J. C. Randall [Macromolecules, 15, 353 (1982), J. Polymer Science, Polymer Physics Ed., 11, 275 (1973)], and K. Kimura

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[Polymer, 25, 441 (1984)]. As the B value is larger, the amount of block-like sequences is smaller and the distribution of ethylene and the alpha-olefin is more uniform. Thus, the copolymer has a narrower composition distribution.

5 distribution.

The composition distribution B value is determined as follows: About 200 mg of the copolymer is uniformly dissolved in 1 ml of hexachlorobutadiene in a sample tube having a diameter of 10 mm, and a ^{13}C -NMR spectrum of the sample is taken usually at a temperature of 120 $^{\circ}\text{C}$ under the following conditions.

10 Measuring frequency: 25.05 MHz

Spectral width: 1500 Hz

Filter width: 1500 Hz

15 Pulse repeating time: 4.2 sec

Pulse width: 7 microseconds

Number of integrations: 2000 to 5000

From the spectrum, P_E , P_O and P_{OE} are determined, and the B value is calculated from them.

20 EXAMPLE 1

Preparation of aluminoxane

A 400 ml flask purged fully with nitrogen was charged with 37 g of $\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$ and 125 ml of toluene. The flask was cooled to 0 $^{\circ}\text{C}$, and 500 millimoles of trimethyl aluminum diluted with 125 ml of toluene was added dropwise. The mixture was heated to 40 $^{\circ}\text{C}$, and the reaction was continued at this temperature for 10 hours. After the reaction, the reaction mixture was subjected to solid-liquid separation by filtration.

30 Toluene was removed from the filtrate to give 13 g of aluminoxane as a white solid. It has a molecular weight, determined by freezing point depression in benzene, of 930. Its m value in the catalyst component [B] was 14.

Polymerization

35 Toluene (500 ml) was introduced into a 1-liter glass autoclave fully purged with nitrogen, and a gaseous

- 34 -

mixture of ethylene and propylene (120 liters/hr, and 80 liters/hr, respectively) was passed through the flask and left to stand at 20 °C for 10 minutes. Then, 0.5 millimole of triisobutyl aluminum was added. Five minutes 5 later, 0.25 milligram-atom, as aluminum atom, of the aluminoxane and subsequently 2.5×10^{-3} millimole of bis(cyclopentadienyl)zirconium dichloride were added, and the polymerization was started. The gaseous mixture of ethylene and propylene was continuously fed, and polymerized at 20 °C under atmospheric pressure for 1 hour. 10 After the polymerization, a small amount of methanol was added to stop the polymerization. The polymer solution was poured into a large excess of methanol to precipitate the polymer. The precipitated polymer was dried at 130 °C under reduced pressure for 12 hours. There was 15 consequently obtained 19.1 g of a polymer having an MFR of 0.31 g/min., an ethylene content, measured by $^{13}\text{C-NMR}$, of 84.1 mole %, an \bar{M}_w/\bar{M}_n of 2.39 and a B value of 1.13.

COMPARATIVE EXAMPLE 1

20 Example 1 was repeated except that in the polymerization of Example 1, triisobutyl aluminum was not used. Hardly any polymer was obtained.

EXAMPLES 2-9 AND COMPARATIVE EXAMPLES 2-6

25 Polymerization was carried out under the conditions described in Table 1 by the same operation as in Example 1. The results are shown in Table 2.

EXAMPLE 10

Polymerization

A 2-liter stainless steel autoclave fully 30 purged with nitrogen was charged with 250 ml of hexane and 750 ml of 4-methyl-1-pentene, and heated to 35 °C. Then, 0.25 millimole of triisobutyl aluminum, 0.5 milligram-atom, calculated as aluminum atom, of the aluminoxane synthesized in Example 1, and 1×10^{-3} millimole of 35 bis(cyclopentadienyl)zirconium dichloride were introduced into the autoclave. Ethylene was subsequently introduced

- 35 -

and the polymerization was started. Ethylene was continuously fed so as to maintain the total pressure at 8 kg/cm²-G; and polymerized at 45 °C for 1 hour. The subsequent operation was carried out in the same way as 5 in Example 1 to give 33.1 g of a polymer having an MFR of 0.55 g/10 min., a density of 0.901 g/cm³, an \bar{M}_w/\bar{M}_n of 2.92 and a decane-soluble weight fraction at room temperature of 1.8 % by weight.

EXAMPLES 11-13 AND COMPARATIVE EXAMPLE 7

10 Polymerization was carried out under the conditions described in Table 3 by the same operation as in Example 10. The results are shown in Table 4.

Table 1

	Transition metal compound (mmol/l)	Alumino-xane (mmol/l)	Alkyl aluminum		Monomer 1		Monomer 2	
			Type	(mmol/l)	Type	(l/hr)	Type	(l/hr)
Example 1	5 x 10 ⁻³	0.5	(i-Bu) ₃ Al	1	ethylene	120	propylene	80
	" 2	" 1	"	"	"	"	"	"
	" 3	" 0.25	"	"	"	"	"	"
	" 4	" 0.5	TMPAL*	"	"	"	"	"
	" 5	"	TEHAL**	"	"	"	"	"
	" 6	2 x 10 ⁻²	"	(i-Bu) ₃ Al	"	"	"	"
	" 7	"	"	"	"	30	"	160
	" 8	5 x 10 ⁻³	"	isopropenyl aluminum	"	-	"	100
	" 9	"	"	ethylene	120	"	"	80
	Comp. Example 1	5 x 10 ⁻³	0.5	-	"	100	"	100
Comp.	" 2	" 1	-	ethylene	120	propylene	80	"
	" 3	" 0.5	Et ₃ Al	"	"	"	"	"
	" 4	"	(n-Bu) ₃ Al	"	"	"	"	"
	" 5	"	(n-C ₆ H ₁₃) ₃ Al	"	"	"	"	"
	" 6	"	(n-C ₈ H ₁₇) ₃ Al	"	"	"	"	"

* TMPAL; Tri(2-methylpentyl)aluminum
 ** TEHAL; Tri(2-ethylhexyl)aluminum

- to be continued -

Table 1 (continued)

	Polymerization temperature (°C)	Polymerization time (hr)	Amount yielded (g)	Activity (g-polymer/mmol-Zr)
Example 1	20	1	19.1	7640
" 2	"	0.5	23.8	9520
" 3	30	1	7.7	3080
" 4	20	"	18.4	7360
" 5	"	"	18.7	7480
" 6	40	"	5.9	590
" 7	20	2	2.0	200
" 8	"	1	10.3	4120
" 9	"	"	9.4	3760
Comp.				
Example 1	20	1	trace	-
" 2	"	0.5	12.2	4880
" 3	"	1	trace	-
" 4	"	"	1.4	560
" 5	"	"	1.4	560
" 6	"	"	0.4	560

Table 2

	MFR (g/10 min.)	Ethylene content (mol%)	\bar{M}_w/\bar{M}_n	B value	$[\eta]^*$ (dl/g)
Example 1	0.31	84.1	2.39	1.13	-
" 2	0.59	83.4	1.95	1.13	-
" 3	0.20	85.2	2.32	1.12	-
" 4	0.30	82.3	2.28	1.15	-
" 5	0.26	80.5	2.03	1.19	-
" 6	-	61.0	1.98	-	0.21
" 7	-	0	2.03	-	0.08
" 8	0.67	85.5	2.36	1.12	-
" 9	3.88	80.1	2.05	1.18	-
Comp. Example 1	-	-	-	-	-
" 2	0.64	83.8	2.37	1.13	-
" 3	-	-	-	-	-
" 4	-	85.4	-	1.11	2.14
" 5	-	85.8	-	1.11	2.20
" 6	-	86.2	-	1.10	2.09

* Measured in decalin at 135°C

Table 3

Transition metal compound (mmol/l)	Alumino-xane (mmol/l)	Alkyl aluminum		Total pressure (kg/cm ² -G)	Comonomer (mL)
		Type	(mmol/l)		
Example 10	1×10^{-3}	0.5	(i-Bu) ₃ Al	0.25	8
" 11	"	"	"	"	4-methyl-1-pentene 750
" 12	"	1	"	0.5	1-hexene 650
" 13	"	0.5	isoprenyl aluminum	0.25	4-methyl-1-pentene 750
Comp. Example 7	1×10^{-3}	0.5	-	-	"
					4-methyl-1-pentene 750

- to be continued -

Table 3 (continued)

	Polymerization temperature (°C)	Polymerization time (hr)	Amount yielded (g)	Activity (g-polymer/mmol-Zr)
Example 10	45	1	33.1	33100
" 11	"	"	35.4	35400
" 12	"	"	48.7	48700
" 13	"	"	18.3	18300
Comp. Example 7	"	"	2.9	2900

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Table 4

	MFR (g/10 min.)	Density (g/cm ³)	\bar{M}_w/\bar{M}_n	n-decane-soluble portion at room temperature (wt %)
Example 10	0.55	0.901	2.92	1.8
" 11	0.46	0.898	2.88	2.1
" 12	0.59	0.904	2.98	2.0
" 13	1.03	0.902	3.02	2.3
Comp. Example 7	0.82	0.910	2.90	0.72

EXAMPLE 14

A 1-liter continuous polymerization reactor was continuously fed with 500 ml/hr of toluene, 0.5 milligram-atom/hr, calculated as aluminum atom, of the aluminoxane synthesized in Example 1, and 5×10^{-3} millimole/hr of bis(cyclopentadienyl)zirconium dichloride, and simultaneously, 150 liters/hr of ethylene, 100 liters/hr of propylene and 1.2 g/hr of 5-ethylidene-2-norbornene (ENB) were continuously fed into the reactor, and polymerized at 20 °C under atmospheric pressure with a residence time of 1 hour and a polymer concentration of 15 g/liter. The resulting polymerization product was worked up as in Example 1 to give an ethylene/propylene/EMB copolymer having an MFR of 2.25 g/10 min., an ethylene content, measured by ¹³C-NMR, of 86.9 mole %, an \bar{M}_w/\bar{M}_n of 2.45, and an iodine value of 11.

COMPARATIVE EXAMPLE 8

Example 1 was repeated except that in the polymerization of Example 1, triisobutyl aluminum was not used, the amount of the aluminoxane was changed to

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2.5 milligram-atoms calculated as aluminum atom, and the polymerization was carried out for 30 minutes. There was obtained 22.8 g of a polymer having an MFR of 1.63 g/10 min., an ethylene content of 82.8 mole %, an \bar{M}_w/\bar{M}_n of 5 1.92 and a B value of 1.14.

EXAMPLE 15

Pre-mixing of the catalyst components [A] and [B]

To a 100 ml glass flask fully purged with nitrogen, 4.7 ml of a toluene solution (Al 0.85 mole/liter) of the aluminoxane synthesized in Example 1, 2.4 ml of a toluene solution (Zr 0.01 mole/liter) of bis(cyclopentadienyl)zirconium dichloride and 12.9 mol of toluene were added, and stirred at 22 °C for 1 hour to give a yellow transparent solution.

15 Polymerization

A 2-liter stainless steel autoclave fully purged with nitrogen was charged with 500 ml of hexane, 500 ml of 4-methyl-1-pentene and 0.5 millimole of tri-isobutyl aluminum, and heated to 47 °C. Thereafter, 2.5 ml of the solution prepared as above was forced into the autoclave under ethylene pressure, and the polymerization was started. Ethylene was continuously fed so as to maintain the total pressure at 7 kg/cm²-G, and the polymerization was carried out at 50 °C for 1 hour. 25 There was obtained 71.4 g of a polymer having an MFR of 1.08 g/10 min., a density of 0.902 g/cm³, an \bar{M}_w/\bar{M}_n of 2.90 and a decane-soluble portion weight fraction at room temperature of of 1.5 % by weight.

EXAMPLE 16

30 Pre-mixing of catalyst components [A] and [B]

The procedure described in Example 15 was repeated except that 4.8 ml of a toluene solution (Zr 0.01 mole/liter) of bis(cyclopentadienyl)zirconium dichloride and 10.5 ml of toluene were used.

35 Polymerization

Example 15 was repeated except that 1.25 ml of the solution prepared above was used. There was obtained

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46.1 g of a polymer having an MFR of 0.82 g/min., a density of 0.904 g/cm³, an \bar{M}_w/\bar{M}_n of 2.86 and a decane-soluble portion weight fraction at room temperature of 1.3 % by weight.

5

EXAMPLE 17

Pre-mixing of catalyst components [A] and [B]

In Example 15, 12.0 ml of a toluene solution (Zr 0.04 mole/liter) of bis(cyclopentadienyl)zirconium dichloride, 6.3 ml of a toluene solution (Al 2.55 moles/liter) of the aluminoxane synthesized in Example 1 and 1.7 ml of toluene were stirred at 22 °C for 30 minutes to give a deep yellow transparent solution.

Polymerization

Example 15 was repeated except that 0.125 ml of the solution prepared above and 1.0 millimole of triisobutyl aluminum were used and the polymerization was carried out at 60 °C for 1 hour. There was obtained 38.5 g of a polymer having an MFR of 1.09 g/10 min., a density of 0.902 g/cm³, an \bar{M}_w/\bar{M}_n of 2.82 and a decane-soluble portion weight fraction at room temperature of 1.3 % by weight.

EXAMPLE 18

Polymerization

A 2-liter stainless steel autoclave fully purged with nitrogen was charged with 500 ml of toluene, 1 milligram-atom, calculated as aluminum atom, of the aluminoxane synthesized in Example 1, and 2 millimoles of triisobutyl aluminum.

Furthermore, propylene was introduced at 5 kg/cm²-G at 30 °C. Thereafter, the introduction of propylene was stopped, and the mixture was cooled to -10 °C. Then, 1×10^{-3} millimole of ethylenebis-(indenyl)zirconium dichloride was introduced into the autoclave, and the polymerization was started. By performing the polymerization at -10 °C for 6 hours, 44.2 g of a polymer was obtained.

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COMPARATIVE EXAMPE 9

Example 18 was repeated except that in the polymerization of Example 18, triisobutyl aluminum was not used. There was obtained 2.4 g of a polymer.

5

EXAMPLE 19

Preparation of aluminoxane

A 400 ml flask fully purged with nitrogen was charged with 37 g of $\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$ and 125 ml of toluene, and cooled to 0 °C. Then, 500 millimoles of 10 trimethyl aluminum diluted with 125 ml of toluene was added dropwise. The temperature was then elevated to 40 °C, and the reaction was continued at this temperature for 10 hours. After the reaction, the reaction mixture was subjected to solid-liquid separation by filtration. 15 Toluene was removed from the filtrate to obtain 13 g of aluminoxane as a white solid. It had a molecular weight, determined by freezing point depression in benzene, of 930. It shows an m value of 14 in catalyst component [B].

20 Preparation of a zirconium catalyst

A 200 ml flask fully purged with nitrogen was charged with 3.8 g of calcined silica obtained by calcining silica (average particle diameter 70 microns, specific surface area $260 \text{ m}^2/\text{g}$, pore volume $1.65 \text{ cm}^3/\text{g}$) 25 at 300 °C for 4 hours, and, 51.5 ml of a toluene solution (Al 0.49 mole/liter) of aluminoxane, and they were stirred at room temperature for 10 minutes. Then, toluene was removed by an evaporator at room temperature to give a solid product. To the solid product was added 30 7.9 ml of a toluene solution (Zr 0.04 millimole/liter) of bis(cyclopentadienyl)zirconium dichloride, and again toluene was removed by an evaporator at room temperature to give a catalyst component having a Zr content of 0.54 % by weight. A gaseous mixture of ethylene and 35 nitrogen (30 liters/hr and 45 liters/hr, respectively) was passed through the resulting catalyst component at

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room temperature for 30 minutes to obtain a solid catalyst component in which ethylene was polymerized in an amount of 0.86 g per gram of the catalyst.

Polymerization

5 A 2-liter stainless steel autoclave fully purged with nitrogen was charged with 900 ml of hexane and 100 ml of 1-hexane, and heated to 45 °C. Then, 1 millimole of triisobutyl aluminum and 0.015 milligram-atom, calculated as zirconium atom, of the zirconium catalyst subjected to prepolymerization with ethylene were charged. The temperature was then elevated to 60 °C. Subsequently, ethylene was introduced and the polymerization was started. Ethylene was continuously fed so as to maintain the total pressure at 7 kg/cm²-G, and the polymerization was carried out at 70 °C for 2 hours. After the polymerization, the polymer slurry was added to a large excess of methanol, and the mixture was filtered. The resulting polymer was dried at 80 °C for 12 hours under reduced pressure to give 101.2 g of a polymer having an MFR of 0.16 g/10 min., a density of 0.916 g/cm³, an \bar{M}_w/\bar{M}_n of 2.98, a bulk density of 0.33 g/cm³ and an n-decane soluble weight fraction at room temperature of 0.31 % by weight. The polymerization conditions, etc. are shown in Table 5.

25

EXAMPLE 20

Example 19 was repeated except that the amount of ethylene prepolymerized was changed to 0.66 g per gram of the catalyst.

Polymerization

30

Example 19 was repeated except that 1-hexane was not used, 1000 ml of hexane was used as a solvent, and ethylene was homopolymerized under a total pressure of 6 kg/cm²-G. The results are shown in Table 6.

COMPARATIVE EXAMPLE 10

35

Polymerization

Example 20 was repeated except that isobutyl

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aluminum was not used. The results are shown in Table 6.

EXAMPLE 21

Polymerization

A 2-liter stainless steel autoclave purged fully with nitrogen was charged with 250 g of sodium chloride (special reagent grade, Wako Pure Chemicals, Co., Ltd.), and dried under reduced pressure at 90 °C for 1 hour. Then, the autoclave was cooled to 65 °C, and the inside of the autoclave was replaced by ethylene. Subsequently, 1 millimole of triisobutyl aluminum, 0.015 milligram-atom, calculated as zirconium atom, of the zirconium catalyst prepared in Example 19, and 10 ml of 1-hexene were introduced. Furthermore, ethylene was introduced, and the total pressure was adjusted to 8 kg/cm²-G. The polymerization was started. Thereafter, only ethylene was supplied, and the polymerization was carried out at 70 °C for 2 hours while maintaining the total pressure at 8 kg/cm²-G. After the polymerization, the reaction mixture was washed with water to remove sodium chloride. The remaining polymer was washed with methanol, and dried overnight at 80 °C under reduced pressure. The polymer was yielded in an amount of 46.8 g, and had an MFR of 1.45 g/10 min., a density of 0.925 g/cm³, an \bar{M}_w/\bar{M}_n of 3.03, a bulk density of 0.31 g/cm³ and an n-decane-soluble portion weight fraction of 0.10 % by weight.

EXAMPLE 22

Example 21 was repeated except that in the polymerization of Example 21, 1-hexene was not used, triisobutyl aluminum and the zirconium catalyst were added at 75 °C, and the polymerization was carried out at 80 °C for 1 hour. The results are shown in Table 6.

EXAMPLES 23-26

Polymerization was carried out under the conditions indicated in Table 5 in the same way as in Example 19. The results are shown in Table 6.

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EXAMPLE 27

Preparation of a zirconium catalyst

A 200 ml flask purged fully with nitrogen was charged with 5.8 g of calcined alumina obtained by calcining alumina (average particle diameter 60 microns, specific surface area $290 \text{ m}^2/\text{g}$, pore volume 1.05 ml/g) at 500°C for 5 hours, 17 ml of a toluene solution (Al 1 mole/liter) of dimethylaluminum monochloride, and 50 ml of toluene, and they were heated at 80°C for 2 hours.

10 The reaction mixture was then subjected to solid-liquid separation by filtration. The solid portion was transferred to 50 ml of toluene, and 32 ml of a toluene solution (Zr 0.04 mole/liter) of bis(cyclopentadienyl)-zirconium dichloride was added. The mixture was heated

15 at 80°C for 1 hour. Again, the mixture was subjected to solid-liquid separation by filtration to give a solid catalyst. The zirconium content of the solid catalyst was 0.27 % by weight. 0.1 milligram, calculated as zirconium atom, of the solid catalyst, 20 ml of a toluene

20 solution (Al 0.49 mole/liter) of the aluminoxane synthesized in Example 19, and 20 ml of toluene were added to the solid catalyst, and the mixture was stirred at room temperature for 30 minutes. Toluene was then removed by an evaporator at room temperature. A gaseous

25 mixture of ethylene and nitrogen (30 liters/hr and 45 liters/hr, respectively) was passed through the resulting catalyst component at room temperature for 30 minutes to give a solid catalyst component in which ethylene was polymerized in an amount of 0.30 g per gram of the catalyst.

30

Polymerization

Polymerization was carried out in the same way as in Example 22. The results are shown in Table 6.

COMPARATIVE EXAMPLE 11

35 Example 27 was repeated except that triisobutyl aluminum was not used. The results are shown in Table 6.

Table 5

Transition metal compound (mmol/l)	Organocalcium compound (C)	Comonomer		
		Type	(mmol)	Type
Example 19	0.015	(i-Bu) ₃ Al	1	7
" 20	"	"	"	6
" 21	"	"	"	8
" 22	"	"	"	"
" 23	"	"	0.5	7
" 24	"	TMPAL*	1	100
" 25	"	TEHAL**	"	"
" 26	"	isoprenyl aluminum	"	"
" 27	"	(i-Bu) ₃ Al	"	"
Comp. Example 10	0.015	"	"	"
" 11	"	"	"	"

* TMPAL; Tri(2-methylpentyl)aluminum

** TEHAL; Tri(2-ethylhexyl)aluminum

- to be continued -

Table 5 (continued)

	Polymerization temperature (°C)	Polymerization time (hr)	Amount yielded (g)	Activity (g-polymer/mmol-Zr)
Example 19	70	2	101.2	6750
" 20	"	"	53.7	3580
" 21	"	"	46.8	3120
" 22	"	"	17.8	1190
" 23	70	2	112.5	7500
" 24	"	"	94.1	6270
" 25	"	"	96.2	6410
" 26	"	"	60.6	4040
" 27	80	1	22.0	1470
Comp. Example 10	70	2	12.2	810
" 11	80	1	5.6	370

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Table 6

	MFR (g/10 min.)	Density (g/cm ³)	\bar{M}_w/\bar{M}_n	Bulk density (g/cm ³)	n-decane-soluble portion at room temperatures (wt %)
Example 19	0.16	0.916	2.98	0.33	0.31
" 20	0.03	-	2.79	0.40	-
" 21	1.45	0.925	3.03	0.31	0.10
" 22	0.19	-	2.88	0.36	-
" 23	0.25	0.920	3.10	0.34	0.25
" 24	0.13	0.915	2.93	0.33	0.29
" 25	0.10	0.914	3.08	0.35	0.27
" 26	0.28	0.918	3.01	0.34	0.24
" 27	0.11	-	3.00	0.38	-
Comp. Example 10	0.04	-	2.70	0.41	-
" 11	0.14	-	3.24	0.34	-

EXAMPLE 28

Preparation of aluminoxane

A 400 ml flask fully purged with nitrogen was charged with 37 g of $\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$ and 125 ml of toluene, and cooled to 0 °C. 500 millimoles of trimethyl aluminum diluted with 125 ml of toluene was added drop-wise. The mixture was heated to 40 °C, and reacted at this temperature for 10 hours. After the reaction, the reaction mixture was subjected to solid-liquid separation by filtration, and toluene was removed from the filtrate to give 13 g of aluminoxane as a white solid. It had a molecular weight, determined by freezing point depression in benzene, of 930. It showed an m value of 14 in catalyst component [B].

Polymerization

A 1-liter glass autoclave fully purged with nitrogen was charged with 500 ml of toluene, and a gaseous mixture of ethylene and propylene (120 liters/hr, and 5 80 liters/hr, respectively) was passed through the autoclave and left to stand for 20 °C for 10 minutes. Thereafter, 0.5 millimole of triisobutyl aluminum was added. Five minutes later, 0.25 milligram-atom, calculated as 10 aluminum atom, of aluminoxane and subsequently, 2.5 x 10⁻³ millimole of bis(cyclopentadienyl)phenoxy-zirconium monochloride were added, and the polymerization was started. A gaseous mixture of ethylene and propylene was continuously fed, and polymerized at 20 °C under atmospheric pressure for 1 hour. After the polymerization, 15 a small amount of methanol was added to stop the polymerization. The polymer solution was added to a large excess of methanol to precipitate the polymer. The polymer precipitate was dried at 130 °C under reduced pressure for 12 hours. The polymer was yielded in an amount of 10.9 g, and had an MFR of 0.21 g/10 min., an 20 ethylene content, determined by ¹³C-NMR, of 85.5 mole %, an \bar{M}_w/\bar{M}_n of 2.35 and a B value of 1.11. The polymerization conditions are shown in Table 7.

COMPARATIVE EXAMPLE 12

25 Example 28 was repeated except that triisobutyl aluminum was not used in the polymerization of Example 28. No polymer was obtained.

EXAMPLES 29-32

30 Polymerization was carried out under the conditions shown in Table 7 by the same procedure as in Example 28. The results are shown in Table 7.

EXAMPLE 33

Preparation of catalyst component (A)

35 Fifty milliliters of a solution of bis(cyclopentadienyl)ethoxyzirconium monochloride (Zr 1.35 millimoles/liter) in toluene was introduced into a 200 ml

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glass flask fully purged with nitrogen. Furthermore, 34 ml of dimethylaluminum chloride (Al 4 millimoles/liter) was added. The mixture was reacted at 25 °C for 30 minutes to give a catalyst component (A).

5 Polymerization

Example 28 was repeated except that the catalyst component (A) prepared as above was used instead of bis(cyclopentadienyl)phenoxyzirconium monochloride.

COMPARATIVE EXAMPLE 13

10 Example 33 was repeated except that triisobutyl aluminum was not used in the polymerization of Example 33. Hardly any polymer was obtained.

EXAMPLES 34-40

15 Polymerization was carried out under the conditions indicated in Table 7 by the same operation as in Example 28. The results are shown in Table 7.

EXAMPLE 41

Polymerization

A 2-liter stainless steel autoclave fully purged with nitrogen was charged with 250 ml of hexane and 750 ml of 4-methyl-1-pentene, and heated to 35 °C. Thereafter, 0.25 millimole of triisobutyl aluminum, 0.5 milligram-atom, calculated as aluminum atom, of the aluminoxane synthesized in Example 1, and 1×10^{-3} milligram-atom, as zirconium atom, of the catalyst component (A) synthesized in Example 6 were introduced. Subsequently, ethylene was introduced, and the polymerization was started. Ethylene was continuously fed so as to maintain the total pressure at $8 \text{ kg/cm}^2\text{-G}$, and the polymerization was carried out at 45 °C for 1 hour. The polymerization product was worked up as in Example 1 to give 30.5 g of a polymer having an MFR of 0.62 g/10 min., a density of 0.902 g/cm^3 , an \bar{M}_w/\bar{M}_n of 2.98 and a decane-soluble portion weight fraction at room temperature of 35 1.9 % by weight.

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EXAMPLE 42

Example 41 was repeated except that in the polymerization of Example 41, 750 ml of 1-hexene was used instead of 4-methyl-1-pentene. There was obtained 28.5 g 5 of a polymer having an MFR of 1.01 g/10 min., a density of 0.891 g/cm³ and an \bar{M}_w/\bar{M}_n of 2.79.

COMPARATIVE EXAMPLE 14

Example 41 was repeated except that in the polymerization of Example 41, triisobutyl aluminum was 10 not used. There was obtained 2.5 g of a polymer having an MFR of 1.94 g/10 min., a density of 0.908 g/cm³, an \bar{M}_w/\bar{M}_n of 2.95 and a decane-soluble portion weight fraction at room temperature of 1.1 % by weight.

EXAMPLE 43

15 A 1-liter continuous polymerization reactor was charged continuously with 500 ml/hr of toluene, 0.5 millimole/hr of tributyl aluminum, 0.5 milligram-atom/hr, calculated as aluminum atom, of the aluminoxane synthesized in Example 28, and 5×10^{-3} milligram-atom/hr, 20 calculated as zirconium atom, of the catalyst component (A) synthesized in Example 40. Simultaneously, 150 liters/hr of ethylene, 100 liters/hr of propylene, and 1.2 g/hr of ethyldene-2-norbornene (ENB) were continuously fed into the reactor. The polymerization was 25 carried out at a temperature of 20 °C under atmospheric pressure with a residence time of 1 hour and a polymer concentration of 14 g/liter. The resulting polymerization product was worked up as in Example 28 to give an ethylene/propylene/ENB copolymer having an MFR of 2.04 30 g/10 min., an ethylene content, determined by ¹³C-NMR, of 85.8 mole %, an \bar{M}_w/\bar{M}_n of 2.49 and an iodine value of 10.

Table 7

	Organometallic compound (b)	Transition metal compound	Aluminoxane (mmol/2)	Alky1 aluminum
	Type	(b)/Zr ¹	Type	Type
Example 28	-	-	Cp ₂ Zr(Oph)Cl	0.5
" 29	-	-	Cp ₂ Zr(Sph)Cl	"
" 30	-	-	Cp ₂ Zr(Oph)Cl	"
" 31	-	-	"	"
" 32	-	-	Cp ₂ Zr(Sph)Cl	"
" 33	(CH ₃) ₂ AlCl	2	Cp ₂ Zr(OEt)Cl	"
" 34	"	"	"	"
" 35	"	"	"	"
" 36	"	"	"	0.25
" 37	"	"	"	"
" 38	(CH ₃) ₃ Al	"	"	"
" 39	Et ₂ AlCl	3	Cp ₂ Zr(OBu)Cl	"
" 40	(CH ₃) ₂ AlCl	2	Cp ₂ Zr(OEt)Cl	"
Comp. Example 12	-	-	Cp ₂ Zr(Oph)Cl	0.5
" 13	(CH ₃) ₂ AlCl	2	Cp ₂ Zr(OEt)Cl	"

- to be continued -

Table 7 (continued)

	Monomer 1		Monomer 2		Polymerization temperature (°C)	Polymerization time (hr)	Amount yielded (g)	Activity (g·polymer/mmol-Zr)
	Type	(ℓ /hr)	Type	(ℓ /hr)				
Example 28	ethylene	120	propylene	80	20	1	10.9	4360
" 29	"	"	"	"	"	0.5	10.1	4040
" 30	"	"	"	"	"	1	9.5	3800
" 31	"	"	"	"	"	"	9.2	3680
" 32	"	"	"	"	"	"	8.8	3520
" 33	"	"	"	"	"	"	18.0	7200
" 34	"	"	"	"	"	0.5	21.5	8600
" 35	"	"	"	"	30	1	7.4	2960
" 36	"	30	"	160	40	"	5.6	560
" 37	"	120	"	80	20	"	18.3	7320
" 38	"	"	"	"	"	"	14.8	5920
" 39	"	"	"	"	"	"	16.9	6760
" 40	"	"	"	"	"	"	11.0	4400
Comp. Example 12	ethylene	120	propylene	80	20	1	0	-
" 13	"	"	"	"	"	"	trace	-

- to be continued -

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Table 7 (continued)

	MFR (g/10 min.)	Ethylene content (mol%)	\bar{M}_w/\bar{M}_n	B value	$[\eta]_2$ (dl/g)
Example 28	0.21	85.5	2.35	1.11	-
" 29	0.42	85.0	2.29	1.12	-
" 30	0.19	83.9	2.30	1.12	-
" 31	0.18	83.0	2.42	1.13	-
" 32	1.54	86.2	2.45	1.10	-
" 33	0.33	83.9	2.34	1.12	-
" 34	0.62	83.2	2.05	1.13	-
" 35	0.25	85.8	2.25	1.10	-
" 36	-	60.7	2.01	-	0.22
" 37	0.28	81.2	2.16	1.18	-
" 38	0.67	86.0	2.33	1.10	-
" 39	0.40	82.9	2.29	1.13	-
" 40	0.37	84.4	2.30	1.12	-
Comp.					
Example 12	-	-	-	-	-
" 13	-	-	-	-	-

Oph: Phenoxy group

Sph: Thiophenyl group

OEt: Ethoxy group

Obu: t-Butoxy group

- 1) Mole ratio at the time of treatment
- 2) Measured in decalin at 135°C
- 3) Tri(2-methylpentyl)aluminum
- 4) Tri(2-ethylhexyl)aluminum

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SCOPE OF CLAIM FOR PATENT

1. A process for polymerizing olefins, which comprises polymerizing or copolymerizing olefins in the presence of a catalyst composed of

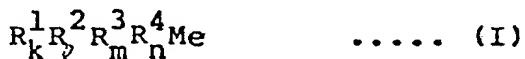
(A) a solid catalyst component composed of a compound of a transition metal of Group IVB of the periodic table supported on an inorganic carrier,

(B) an aluminoxane, and

(C) an organoaluminum compound having a hydrocarbon group other than n-alkyl groups.

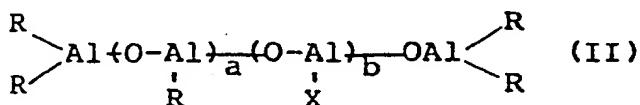
2. The process set forth in claim 1 wherein the transition metal is titanium, zirconium or hafnium.

3. The process set forth in claim 1 wherein the transition metal compound is represented by the following formula (I)



wherein R^1 represents a cycloalkadienyl group, R^2 , R^3 and R^4 are identical or different and each represents a cycloalkadienyl group, an aryl group, an alkyl group, a cycloalkyl group, an aralkyl group, a halogen atom, a hydrogen atom, or a group of the formula $-OR^a$, $-SR^b$ or $-NR_2^c$ in which each of R^a , R^b and R^c represents an alkyl group, a cycloalkyl group, an aryl group, an aralkyl group or an organic silyl group, Me represents zirconium, titanium or hafnium, k is 1, 2, 3 or 4, ℓ , m and n are each 0, 1, 2 or 3, and $k+\ell+m+n=4$.

4. The process set forth in claim 1 wherein the aluminoxane is represented by the following formula (II)

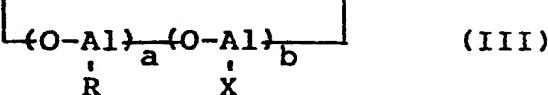


wherein R is a hydrocarbon group, X is a halogen atom, and \underline{a} and \underline{b} , independently from

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each other, represent a number of 0 to 80 with the proviso that a and b are not simultaneously zero,

or the following formula (III)

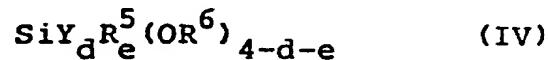


wherein R, X, a and b are as defined above with regard to formula (II).

5. The process set forth in claim 1 wherein the inorganic carrier is treated with an organometallic compound or a halogen-containing silicon compound prior to deposition of the transition metal compound on it.

6. The process set forth in claim 1 wherein the organometallic compound is an organoaluminum compound, and organoboron compound, an organomagnesium compound, an organozinc compound or an organolithium compound.

7. The process of claim 1 wherein the halogen-containing silicon compound is represented by the following formula (IV)



wherein Y represents a chlorine or bromine atom, R⁵ and R⁶, independently from each other, represent a hydrogen atom, an alkyl group having 1 to 12 carbon atoms, an aryl group or a cycloalkyl group having 3 to 12 carbon atoms, d is a number of 1 to 4, and e is a number of 0 to 4, with the proviso that the sum of d and e is a number of 1 to 4.

8. The process set forth in claim 1 wherein the inorganic carrier is a porous inorganic oxide.

9. The process set forth in claim 1 wherein the organic group of the organoaluminum compound is a

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branched alkyl group, a cycloalkyl group or an aryl group.

10. A process for producing olefins, which comprises polymerizing or copolymerizing the olefins in the presence of a catalyst composed of

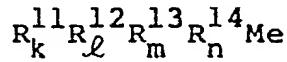
(A)' a compound of a transition metal of Group IV of the periodic table containing a ligand having a conjugated π -electron and a ligand containing a hetero atom capable of being bonded to the transition metal and selected from the group consisting of oxygen, sulfur, nitrogen and phosphorus,

(B) an aluminoxane, and

(C) an organoaluminum compound having a hydrocarbon group other than n-alkyl groups.

11. The process set forth in claim 10 wherein the transition metal is titanium, zirconium or hafnium.

12. The process set forth in claim 10 wherein the transition metal compound is represented by the following formula (I)'



wherein R^{11} is cycloalkadienyl, R^{12} is selected from the class consisting of $-OR^a$, $-SR^b$, $-NR_2^c$ and $-PR_2^d$, R^{13} and R^{14} , independently from each other, represent cycloalkadienyl, aryl, aralkyl, alkyl, halogen or hydrogen, R^a , R^b and R^c represent alkyl, cycloalkyl, aryl, aralkyl or organic silyl, Me is zirconium, titanium, or hafnium, k and ℓ are 1, 2 or 3, m and n are 0, 1 or 2 and $k+\ell+m+n=4$.

13. The process set forth in claim 10 wherein the aluminoxane is represented by the formula (II) given above.

14. The process set forth in claim 10 wherein the organic group of the organoaluminum compound is a branched alkyl group, a cycloalkyl group or an aryl group.

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15. The process of claim 10 wherein the transition metal compound is treated with an organometallic compound.

16. The process of claim 15 wherein the organometallic compound is an organoaluminum compound, an organoboron compound, an organomagnesium compound, an organozinc compound or an organolithium compound.

17. A process for polymerizing or copolymerizing olefins in the presence of a catalyst composed of

(A) a compound of a transition metal of Group IVB of the periodic table,

(B) an aluminoxane in a concentration of not more than 3 milligrams/liter as aluminum atom in the reaction system, and

(C) an organoaluminum compounds having a hydrocarbon group other than n-alkyl groups.

INTERNATIONAL SEARCH REPORT

International Application No

PCT/JP87/00696

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ³

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl⁴ C08F10/00, C08F4/64

II. FIELDS SEARCHED

Minimum Documentation Searched ⁴

Classification System	Classification Symbols
IPC	C08F10/00, C08F110/00, C08F210/00 C08F4/64, C08F4/66

Documentation Searched other than Minimum Documentation
to the Extent that such Documents are Included in the Fields Searched ⁵

III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴

Category ⁶	Citation of Document, ¹⁶ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸
X	JP, A, 60-130604 (Idemitsu Kosan Co., Ltd.) 12 July 1985 (12. 07. 85) Claim (Family: none)	17
Y	JP, A, 60-130604 (Idemitsu Kosan Co., Ltd.) 12 July 1985 (12. 07. 85) Claim (Family: none)	1-16
X	JP, A, 60-260602 (Idemitsu Kosan Co., Ltd.) 23 December 1985 (23. 12. 85) Claim (Family: none)	17
Y	JP, A, 60-260602 (Idemitsu Kosan Co., Ltd.) 23 December 1985 (23. 12. 85) Claim (Family: none)	1-16
A	JP, A, 58-19309 (Hoechst A.G.) 4 February 1983 (04. 02. 83) Claim & US, A, 4542199	1-17

* Special categories of cited documents: ¹⁵

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "S" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search ²

November 13, 1987 (13.11.87)

Date of Mailing of this International Search Report ²

November 30, 1987 (30.11.87)

International Searching Authority ¹Signature of Authorized Officer ²⁰

Japanese Patent Office

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	JP, A, 60-35006 (Exxon Research & Engineering Co.) 22 February 1985 (22. 02. 85) Claim & EP, A, 128046	1-17
A	JP, A, 60-35007 (Exxon Research & Engineering Co.) 22 February 1985 (22. 02. 85) Claim & EP, A, 129368	1-17
A	JP, A, 60-35008 (Exxon Research & Engineering Co.) 22 February 1985 (22. 02. 85) Claim & US, A, 4530914	1-17

V. OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE¹⁰

This International search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. Claim numbers, because they relate to subject matter¹¹ not required to be searched by this Authority, namely:

2. Claim numbers, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out¹², specifically

VI. OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING¹³

This International Searching Authority found multiple inventions in this international application as follows

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid specifically claims:
3. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims. It is covered by claim numbers
4. As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee

Remark on Protest

The additional search fees were accompanied by applicant's protest
 No protest accompanied the payment of additional search fees

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